GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

no action
9/25 ok

Date: 9/21/78

Project Title: Radar Cross-Section Measurements of Insects

Project No: B-520

Project Director: Mr. E. F. Greneker

Greneker

Sponsor: U. S. Dept. of Agriculture; Western Cotton Research Laboratory; Phoenix, Ariz. 85040

Agreement Period: From 8/1/78 Until 10/31/78

Type Agreement: GIT Letter of 8/16/78 in confirmation of USDA/WCRL letter dated 7/19/78 (referencing USDA South Reg. Coop. Agree. No. 12-14-7001-60 w/GIT).

Amount:
$4,500

Reports Required:
Final Letter Report

Sponsor Contact Person (s):

Technical Matters

Mr. Wayne W. Wolf
Agricultural Engineer
Phone: 602/261-3524

Contractual Matters
(thru OCA)

(Administrator unknown)
Procurement Office
Phone: 602/261-3714

U.S. Department of Agriculture
Western Cotton Research Laboratory
4135 E. Broadway Road
Phoenix, Ariz. 85040

Defense Priority Rating: None.

Assigned to: Radar Instrumentation Laboratory (School/Laboratory)

COPIES TO:

- Project Director
- Division Chief (EES)
- School/Laboratory Director
- Dean/Director—EES
- Accounting Office
- Procurement Office
- Security Coordinator (OCA) ✓
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- EES Reports & Procedures
- Project File (OCA)
- Project Code (GTRI)
- Other

CA-3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: April 4, 1980

Project Title: Radar Cross-Section Measurements of Insects

Project No: B-520

Project Director: E. F. Greneker

Sponsor: U.S. Department of Agriculture; Western Cotton Research Laboratory; Phoenix, Ariz. 85040

Effective Termination Date: October 31, 1978

Clearance of Accounting Charges: ---

Grant/Contract Closeout Actions Remaining:

NONE

_ Final Invoice and Closing Documents
_ Final Fiscal Report
_ Final Report of Inventions
_ Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other _____

Assigned to: RAIL/RAD (School/Laboratory)

COPIES TO:

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Project File (OCA)
Project Code (GTRI)
Other _____

CA–4 (1/79)

B-520

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

August 29, 1979

United States Department of Agriculture
Western Cotton Research Lab
4135 East Broadway Road
Phoenix, Arizona 85040

Attention: Mr. Wayne W. Wolf

Reference: Cooperative Agreement No. 12-12-7001-60 (7/19/78)

Subject: Final Report - Measurements of Radar Returns from Insects (Georgia Tech Project B-520)

Gentlemen:

This report covers the radar cross-section measurements which were conducted at the Planet Ranch located near Lake Havasu City, Arizona during the period 31 August 1978 through 2 September 1978. The measurements were supported by Mr. Wayne W. Wolf and Ms. Beverly Green of the U.S.D.A.; Mr. E. E. Martin, Mr. Mark Corbin and Mr. Sam Thomas of the Georgia Institute of Technology.

Introduction

Widespread application of chemical pesticides as a solution to insect control for agricultural purposes is coming under increased criticism because of the threat posed to the enviroment. While there is no practical alternative to pesticides, environmental and economic advantages could be realized if the pesticides were more effectively distributed. The ability to predict insect dispersal behavior and population concentrations could significantly increase the effectiveness of current pesticide distribution programs while decreasing the amount of pesticide required.

Scientists within the radar community have attributed certain false or otherwise unexplained radar echos to the presence of birds and insects. Investi-

gations have shown that insects are detectable by radar, and measurements have been made to determine the radar cross-section of a number of insect species. 1

The United States Department of Agriculture has begun a modest program to determine if radar techniques can be effectively applied to the insect control problem. The program is being conducted under the direction of Mr. Wayne W. Wolf at the Western Cotton Research Laboratory, Phoenix, Arizona. The Georgia Institute of Technology, Engineering Experiment Station (EES) was asked to conduct an experiment at a facility operated by the Defense Nuclear Agency (DNA) near Lake Havasu City, Arizona. Two instrumentation radars previously installed at the DNA test site were used to support the experiment which was designed to measure the radar cross-section of insects, supplied by the Department of Agriculture, at frequencies of 10 GHz and 35 GHz, and to compare the results to determine if a higher radar frequency would offer a significant advantage for insect detection.

Results of the experiment indicated excessively high radar cross-section values at both frequencies. These high values are thought to be the result of radar antenna sidelobe illumination of and reflections from the "kitoon" (large balloon), used to support the insect.

Technical Considerations

Measurements of small values of radar cross-section associated with insects require special considerations in the instrumentation and set up of the experiment. An X-band radar cross-section of $1.2 \times 10^{-6} m^2$ was assumed for the cabbage louper moth (Trichoplusiani). Because the moth has such a small radar cross-section, it is mandatory that the moth be totally removed from other objects which would interfere with the measurement. Two methods of isolating the moth from the vegetation and

1 E. F. Greneker and M. A. Corbin, "Radar Reflectivity of Airborne Insects, A Literature Survey", Final Technical Report, Georgia Tech Project B-501, June 1978.

ground clutter were considered. The first method was to suspend the insect from a nylon monofilament stretched between two widely separated vertical supports. This method, while being capable of holding the insect at a fixed point in space, would have required the installation of very tall supports because of the geometry of the measurement site and was considered too costly and time consuming to be accomplished within the scope of the program. The second method was to suspend the insect from a monofilament supported by a "kitoon." This method has been successfully used; however, it suffers from the lack of stability and its position is influenced by very light winds.

The beamwidth of the antennas used on these radars was 0.7 degrees. Theoretical calculations based on the radar parameters indicated that the maximum range of detectability for a cross-section of $1.2 \times 10^{-6} m^2$ (typical for a cabage louper) was 2094 meters. The range chosen for these measurements (720 meters) was a compromise between an adequate signal to noise ratio and the diameter of the radar beam. At this range, a signal-to-noise ratio of 18 dB was expected with a 3 dB beam diameter of 8 meters. This small beam diameter placed stringent requirements on kitoon stability. The prevailing winds were from the east at about 65 degrees to the direction of the radar. A 3-point suspension was used in an effort to increase the stability of the kitoon. This was accomplished by tying three monofilament lines 200 feet below the kitoon and suspending the insect from that point. During the measurements, the insect was suspended about 200 feet above the ground and 200 feet below the kitoon.

Experimental Results

The results of this experiment were directly affected by the wind conditions which existed over the three day measurement period. During the first two days, the inability to maintain the target insect within the small volume of space defined by the radar pulse width and the antenna beamwidth prevented the collection of any data. The physical size of the targets were too small to be seen on a television boresite monitor mounted on the radar antennas; therefore,

locating and tracking the insect was not possible and radar returns were seen only for occasional brief periods as the insect passed through the radar beam. The desert winds were very light during the early morning of the third day and radar signals from four targets suspended about 200 feet below the kitoon were recorded. The targets for which data were recorded are listed below:

1. Sphere - 3.7 cm diameter, gold plated
2. 10 Insects - capitive inside styrofoam cup container
3. Styrofoam cup container only
4. Single insect

The 3.7 cm spherical target was intended to serve as an absolute cross-section reference for calibration of the radar system. The radar cross-section of this spherical target at 9.375 GHz and 35 GHz is -27.8 dBsm and -30.1 dBsm, repectively. The signal from the calibration target was attenuated in 3 db steps from the peak value to 39 dB below the peak, approximately corresponding to the system noise level. After the calibration was recorded, 10 cabbage louper moths were placed inside two styrofoam cups. The cups were cemented together to form a single cavity containing the 10 insects. The cups containing the target insects were raised to an altitude of approximately 200 feet and data were recorded for about 40 seconds at each frequency. The insects were removed from the styrofoam cups and data were recorded for an additional 40 seconds. The radar signal from the styrofoam cups alone was significant when compared to the return received from the insects inside the cups. A single insect was then attached to a monofilament and suspended at an altitude of about 200 feet. Data were recorded for about 20 seconds at each frequency. At this point in the test schedule, the winds has increased to a point that targets could no longer be confined within the radar beam and no additional data were collected.

Analysis of the data at the Data Reduction Facility at Georgia Tech revealed several inconsistencies: (1) variations of about 10 dB were seen in the calibration from the sphere, (2) the peak radar cross-section of the 10 insects in

the styrafoam cups was 5 dB lower at 9.375 GHz and 15 dB lower at 35 GHz than the corresponding signal received from the cups only, and (3) for the single insect measurement the estimated average radar cross-section at 9.375 GHz exceeded the expected average cross-section by about 5 dB with variations from 6.4 cm^2 to 0.002 cm^2. (The estimated average radar cross-section from the recorded data was 0.04 cm^2.) If a square law frequency relationship is assumed, the difference between the radar cross-section values at 9.375 GHz and at 35 GHz is 11.4 dB. The average of the radar cross-section of the single insect which was measured at 35 GHz exceeded this value by 14 dB.

Variations in these data indicate the presence of an interfering signal. This interference could have originated from sidelobe illumination of either the ground or the kitoon. The geometry of the measurement site indicate the most probable source of the interference was direct illumination of the kitoon by the antenna sidelobes.

Conclusions

Measurements of extremely small radar cross-sections such as those of insects require special considerations in the method used to support the target. The kitoon used in this experiment is an acceptable solution to the support problem provided that certain geometrical and meteorologial conditions exist. These conditions were not met during this experiment because of the winds which affected the target position and because of other unknown parameters associated with the geometry of the measurements and of the field site. The measurements can best be accomplished on a well instrumented radar range where equipment and site parameters can be controlled.

Respectfully submitted.

Edward E. Martin
Senior Research Engineer

Approved by:

Eugene F. Greneker, Acting
Chief Radar Applications Division

EEM/dw